Pacific Northwest
NATIONAL LABORATORY

Electric Vehicles at Scale

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Project ID: van039

Overview

Project Details

Timeline

Start: June 2020
End: September 2021
Percent Complete: 65%

Budget

Total funding: $550k
DOE Cost Share: 100%

Partners

Southern California Edison

Electric Vehicles at Scale (Phase 2) – Distribution Grid Impacts

Challenge

❑ Wide-scale adoption of Electric Vehicles (EVs) could be limited if we don't address the distribution system challenge

❑ Distribution system planning practices don't reflect adequately the locational aspects and characteristics of growing EV loads.

Barriers

❑ System Analysis is difficult because of large diversity in distribution system circuits across the country (e.g., customer composition, circuit topology) challenges tool development.

❑ Uncertainty surrounding EV adoption, charging infrastructure and human behaviors makes distribution investment planning difficult.

❑ Lack of efficient methodologies and data to estimate adoption at circuit & customer-level EV adoption.

Relevance

Electric Vehicles at Scale (Phase 2) - Scope

Key Research Questions

❑ How to determine the EV hosting capacity of distribution system circuits?

❑ How does mitigation through smart charge management enhance EV hosting capacity?

❑ How can distribution planning tools be updated to plan for EV growth?

Outcomes

1. Socio-economic EV forecast and adoption methodology that forecasts circuit-level EV adoption.
2. Open-source toolset in support of utility planning and investment decisions.
3. Results and methodology of high interest to SCE. SCE will adopt methodology for all SCE circuits
4. Insights into value of smart charge management

Impact on Barriers

❑ The socio-economic EV adoption forecast methodology provides customer & feeder-level forecasts.

❑ The methodology uses household income and home price data, key drivers for EV adoption, to minimize forecast uncertainty.

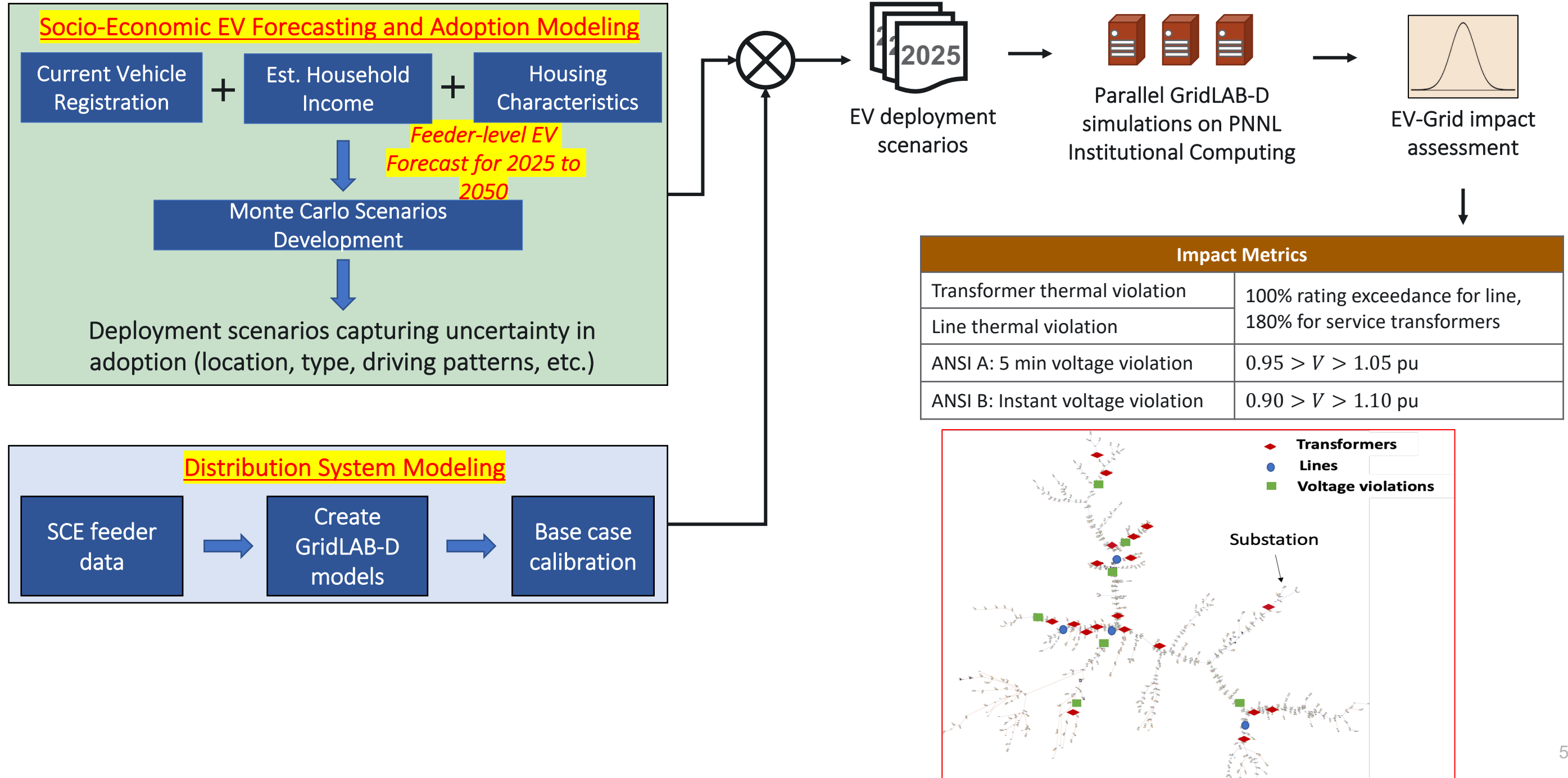### Impact on Sub-program Objectives

This project enables utility analysts and distribution planners to plan for infrastructure upgrades to avoid infrastructure limitation hindering continual growth in EV adoption

Milestones

	Deliverable	Deadline	Status
1	Briefing material on scope of distribution analysis and all of the assumptions	November 2020	**Complete**
2	Intermediate results reporting: Preliminary results from application of hosting capacity analysis and smart charge management controls on SCE circuits.	February 2021	Delayed. Revised estimate 6/30
3	Briefing on lessons learned, outline of guideline of EV integration into distribution planning processes	May 2021	Delayed. Revised estimate: 9/30
4	Final report on analysis and guideline document	July 2021	Delayed. Revised estimate: 9/30

Delays due to NDA process with CA DMV and SCE. NDA signed on 5/7/2021.

Approach and Methodology

Socio-Economic EV Forecasting and Adoption Modeling

Current Vehicle Registration + Est. Household Income + Housing Characteristics

Feeder-level EV Forecast for 2025 to 2050

Monte Carlo Scenarios Development

Deployment scenarios capturing uncertainty in adoption (location, type, driving patterns, etc.)

Distribution System Modeling

SCE feeder data → Create GridLAB-D models → Base case calibration

EV deployment scenarios

Parallel GridLAB-D simulations on PNNL Institutional Computing

EV-Grid impact assessment

Impact Metrics	
Transformer thermal violation	100% rating exceedance for line, 180% for service transformers
Line thermal violation	
ANSI A: 5 min voltage violation	$0.95 > V > 1.05$ pu
ANSI B: Instant voltage violation	$0.90 > V > 1.10$ pu

Legend:
- ◆ Transformers
- ● Lines
- ■ Voltage violations

Substation

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Novelty in Approach

❑ Data sources: Block income distributions, home prices, housing attributes (access to charging), vehicle registrations

❑ Projections of EV adoption by households that can be located on the map for distribution planning.

❑ Adoption model can be calibrated to local, regional, state EV goals
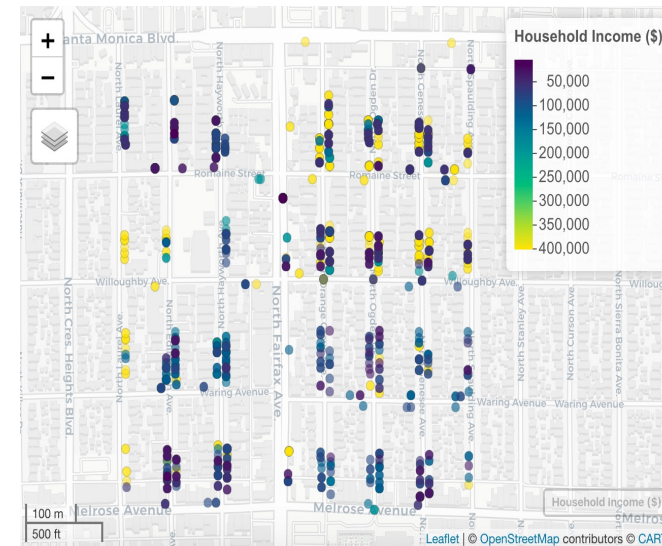
Key Takeaways

❑ Key driver for EV adoption
  ❑ Household income
  ❑ Access to charging (housing characteristics)

❑ Forecasts for EV adoption will be produced down to the neighborhood level, which will then be mapped to feeder to generate circuit-level EV adoption forecast for every study year.

2020   2030   2050
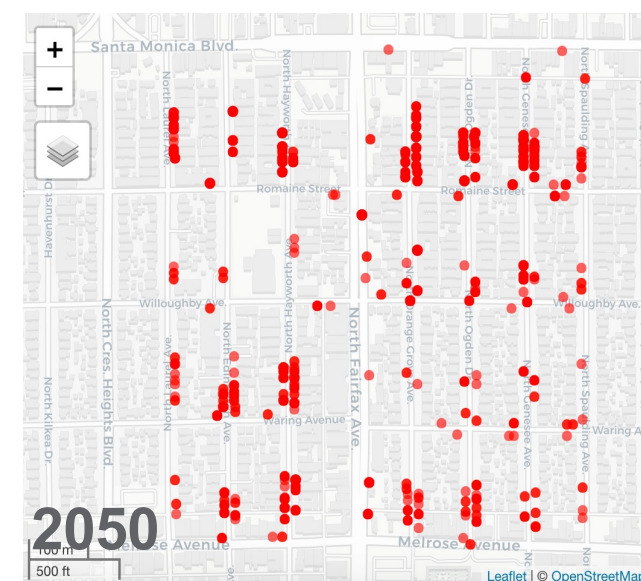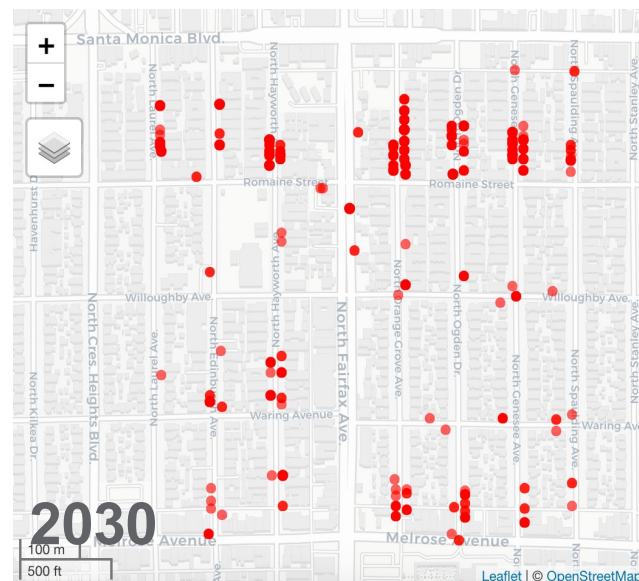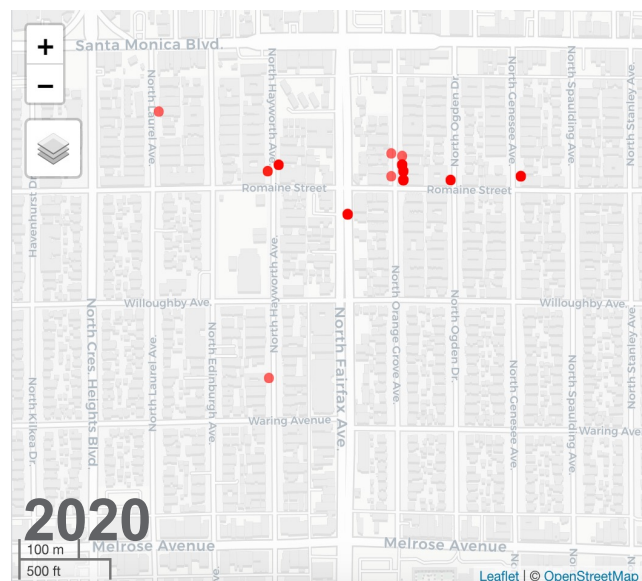
Technical Accomplishments and Progress
## New High-Resolution Socio-Economic LDV EV Adoption Model

Example: Application to region in West Hollywood, CA

❑ Existing household vehicle registration was obtained from California Department of Motor Vehicles

❑ Household income estimated from county tax assessor's data and Census Bureau's income distribution data at the block level; charging accessibility inferences based on housing characteristics also from tax assessor data

❑ Assumes dedicated market transformation effort by the California Energy Commission and Southern California Edison to obtain 'zero emission vehicle' goals

Key Takeaways

❑ We can calibrate the model with State, municipal, or utility targets for EV penetration for a given future year

Preliminary results

EV Adoption Over Time
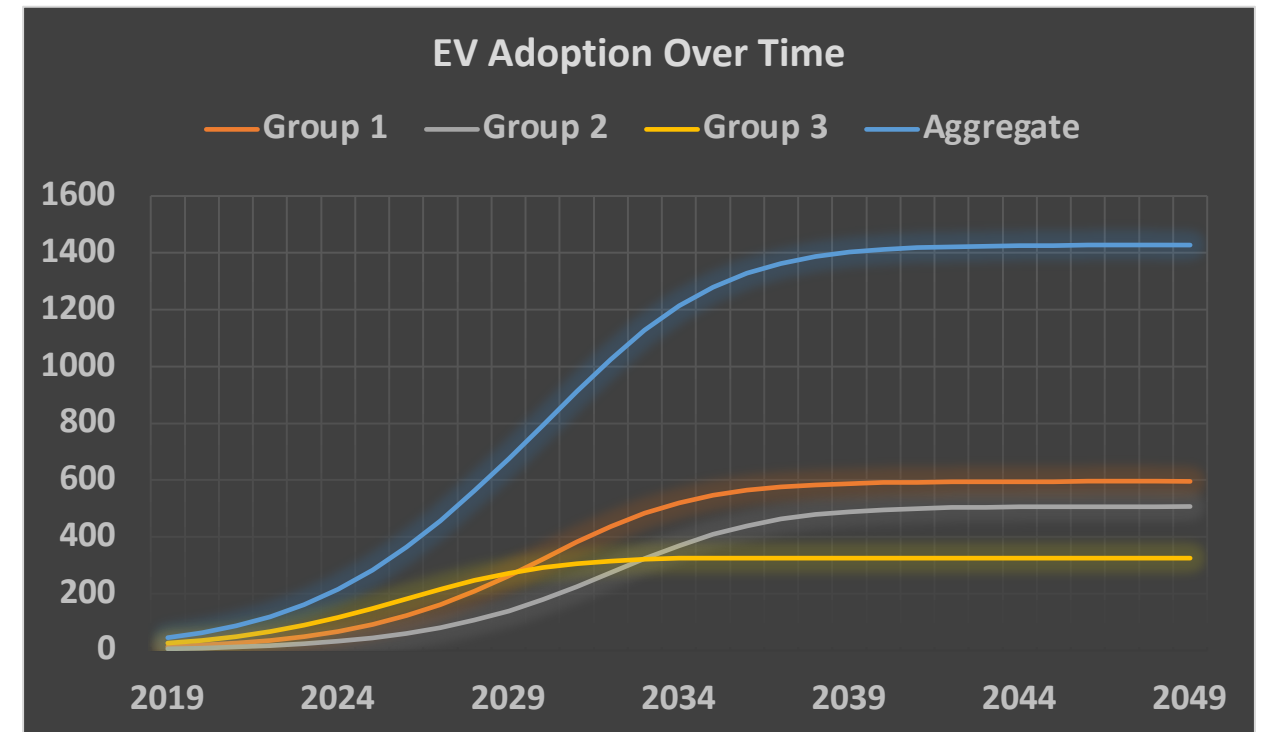
	Group 1	Group 2	Group 3
EV Range	25-300 mi	60-275 mi	PHEV 18-80 mi
Max Adoption	595	507	325

Technical Accomplishments and Progress

Grid Analysis with GridLAB-D Prototypical Feeder

Percentage of transformers, lines and nodes with violations
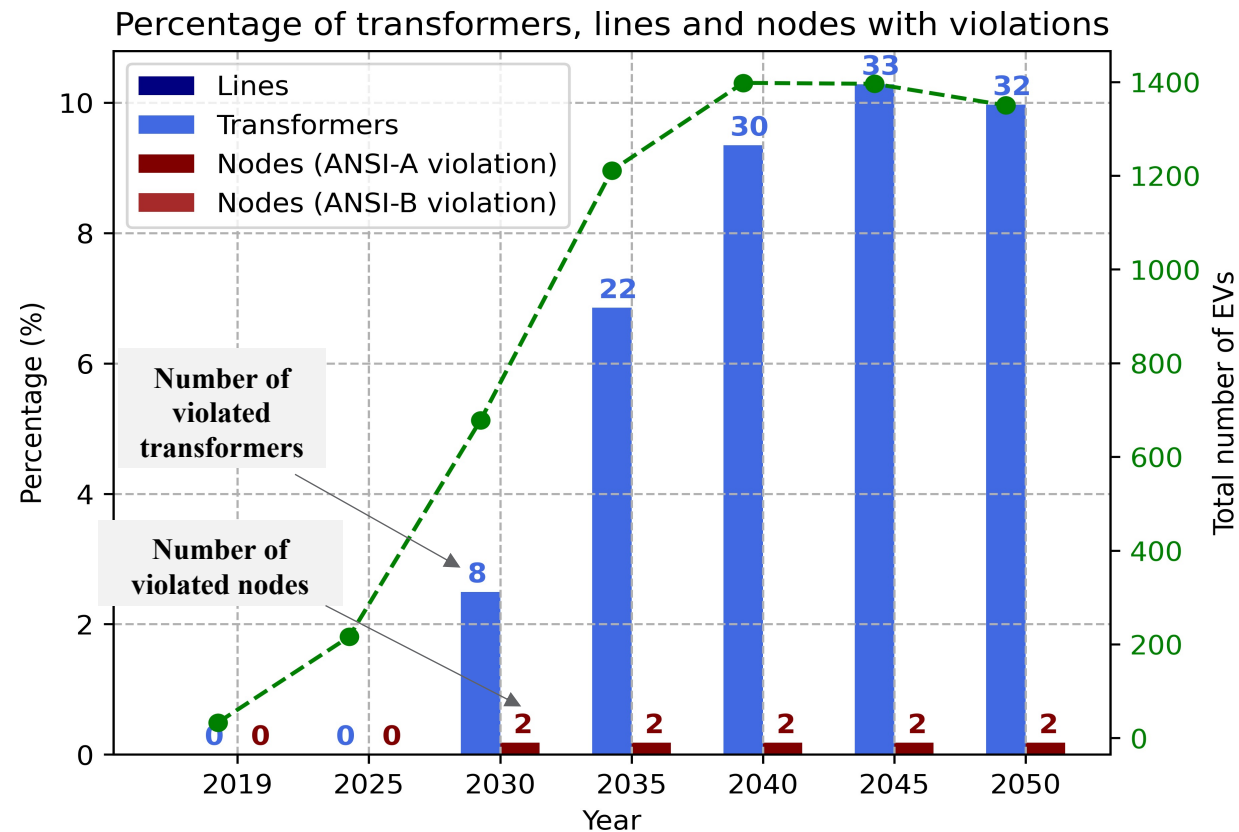
Impact Metrics

Transformer thermal violation	180% for service transformers 100% rating exceedance for line,
Line thermal violation	
ANSI A: 5 min voltage violation	$0.95 > V > 1.05$ pu
ANSI B: Instant voltage violation	$0.90 > V > 1.10$ pu

Simulation Details

- Study years: 2025 to 2050 in 5-year increments
- Duration: Summer [June, July, August]. Can be over 1-year
- 500 adoption scenarios randomly drawn for each study year
- A grid component is flagged if its operating limit is violated for more than cumulative 2 hours in more than 5% scenarios
- Develop mitigation scenarios: smart charge management, infrastructure upgrades

Key Takeaways

☐ Analysis will identify constrained components in the grid infrastructure

☐ Analysis will provide location-specific bottlenecks as a function of time, guiding utility investment decisions

☐ Mitigation analysis will include smart charge management and infrastructure upgrade as options

Collaboration & Coordination

❏ Southern California Edison, Utility partner

- ▪ Not funded by DOE
- ▪ Role:
  - o Provide SCE feeder circuit data to enable analysis using realistic models
  - o Work tightly with PNNL technical team to adopt methodologies for their own analyses
- ▪ Expected benefits to SCE and other utilities:
  - o High interest in the EV adoption modeling. SCE's current EV adoption approach not as granular
  - o SCE interested in applying EV adoption methodology to larger number of circuits
  - o Methodology directly applicable to other utility organizations

Remaining Challenges and Barriers

❑ Research challenges and barriers

    ❑ Modeling adoption at multi-unit dwellings

    ❑ Adoption model for commercial fleets at the feeder level (L/M/HDV)

    ❑ User behavior modeling – how EV owners charge their cars?

❑ Impact challenges and barriers

    ❑ PNNL approach requires cluster computing. Only large utility may have computation capabilities to use PNNL developed Methodology and Open-Source scripts

    ❑ Tech transfer funding is required to ensure methodology is accessible to smaller utilities with limited computational infrastructure (non-cluster computing)

    ❑ Socio-economic data for states other than CA may not be readily available

Remaining Research

Plans for rest of FY21:

❑ Apply PNNL's EV forecasting methodology and determine impact to specific SCE circuit operation

❑ Perform valuation (investment vs. benefits) of smart charge management and traditional infrastructure upgrade strategies as mitigation

Proposed Future Research (FY22)

❑ Technology transfer of EV@scale, Phase II outcomes with large and small utility organization

    ❑ Planning for simplified approach that could be performed by small PUD

    ❑ Education and outreach: dissemination of open-source methodologies

❑ Enhancement of EV penetration model for commercial fleets (LDV, MDV, HDVs) and integration into grid modeling scripts
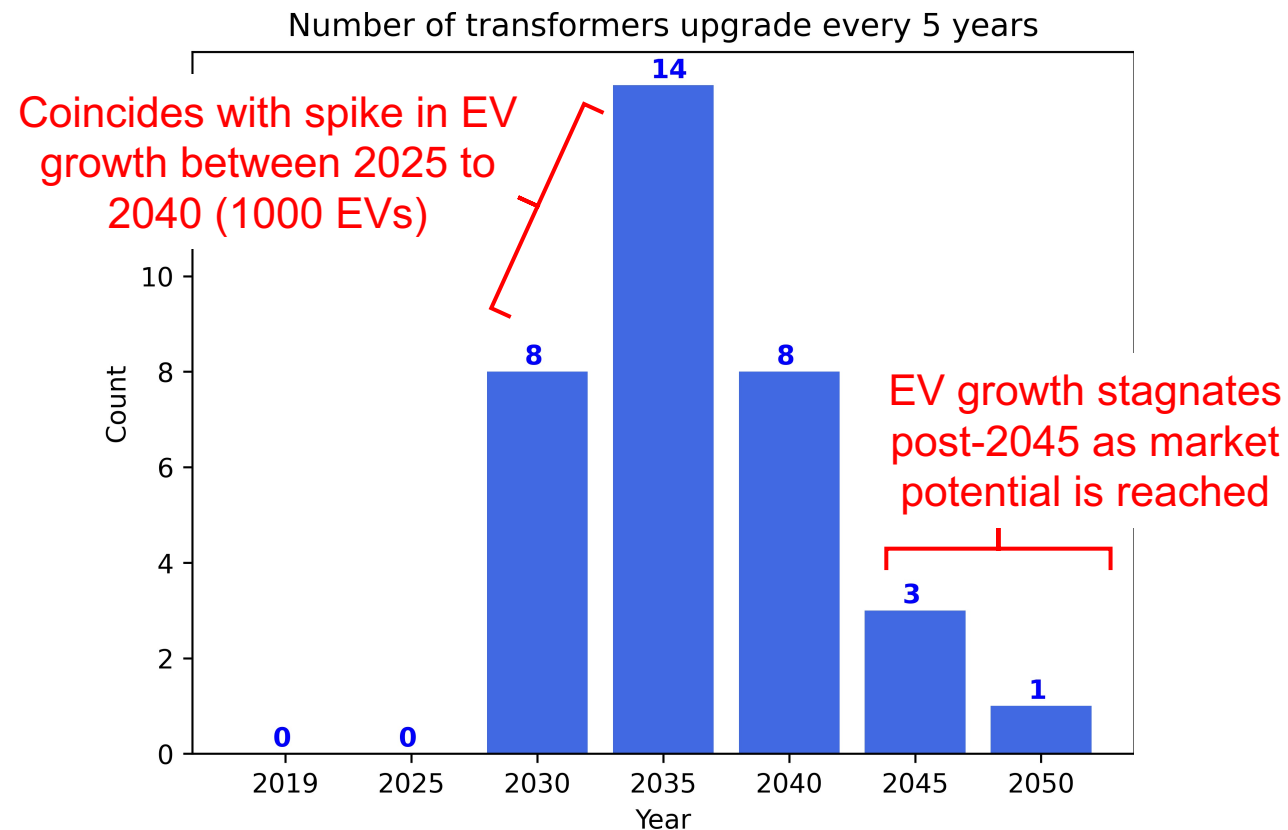
Summary

❑ Circuit-level EV adoption forecasting is essential to effectively determine impact of EV charging on feeder operation

❑ Current utility planning tools need to be updated with circuit-specific EV adoption models to accurately determine circuit upgrades necessary to accommodate EV growth

❑ The outcomes from this project directly address these needs:

- A socio-economic EV adoption forecast methodology that outputs circuit-level adoption

- An open-source toolset for utilities to perform infrastructure upgrade planning in the context of EVs

❑ Results from this study will be disseminated to broader audiences: universities, distribution planners

Technical Back-Up Slides

Technical Accomplishments and Progress

Grid Analysis with GridLAB-D Prototypical Feeder

Number of transformers upgrade every 5 years

Coincides with spike in EV growth between 2025 to 2040 (1000 EVs)

EV growth stagnates post-2045 as market potential is reached

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Impact Metrics

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Key Takeaways

- ❑ Analysis will identify constrained components in the grid infrastructure
- ❑ Results from the tool will provide location-specific bottlenecks as a function of time, guiding utility investment decisions
- ❑ Mitigation analysis will include smart charge management and infrastructure upgrade as options